National Aeronautics and
Space Administration

Imaging Deformation of Large Earthquakes with ALOS-2 ScanSAR

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with help from
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and Paul Lundgren

ARIA and collaborators
Jet Propulsion Laboratory
California Institute of Technology

ALOS-2 projects

- RA4 PI 1372: Integrated Imaging for Fault Ruptures of Large Earthquakes with ALOS-2 data

- RA6 PI 3278: Integrated Imaging for Fault Slip of Large Earthquakes with ALOS-2 data

- RA6 PI 3277: Environmental controls on landslide motion revealed by InSAR with ALOS-2 data

ALOS-2 module for ISCE

- A new module for ALOS-2 InSAR processing
- written by Cunren Liang for the JPL-Stanford InSAR Scientific Computing Environment (ISCE) package
- handles all combinations of stripmap (SM1, SM2, SM3) and ScanSAR (WD1, WD2) modes of PALSAR-2 data
- range and azimuth spectra filtered to optimize InSAR for all combinations
- includes ionospheric corrections based on split-spectrum method
- extraction of original bursts allows multiple-aperture interferometry (MAI) to measure along-track deformation

ALOS-2 InSAR method publications

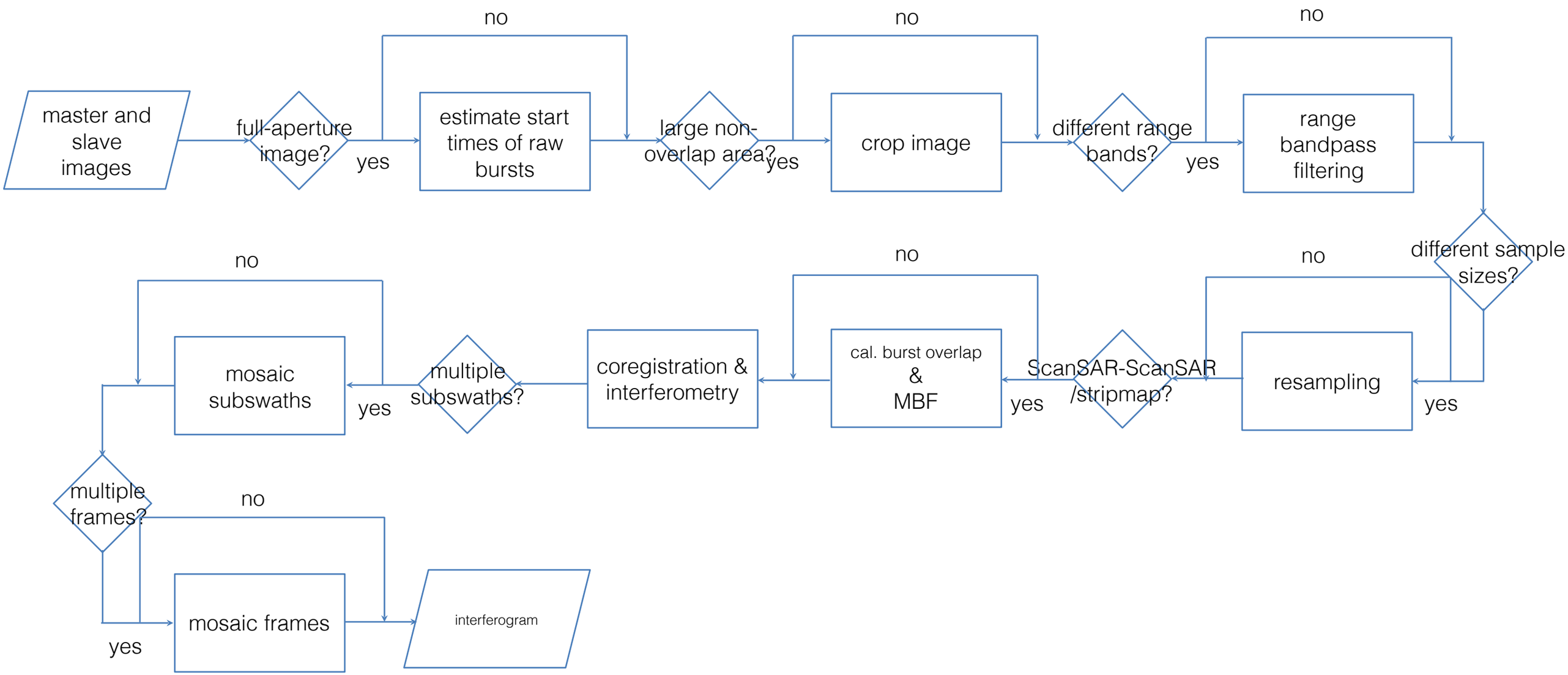
- Liang, C., and E. J. Fielding (2016), Interferometric Processing of ScanSAR Data Using Stripmap Processor: New Insights From Coregistration, IEEE Transactions on Geoscience and Remote Sensing, 54(7), 4343-4354, doi: 10.1109/TGRS.2016.2539962.

- Liang, C., and E. J. Fielding (2017), Measuring Azimuth Deformation With L-Band ALOS-2 ScanSAR Interferometry, IEEE Transactions on Geoscience and Remote Sensing, 55(5), 2725-2738, doi:10.1109/TGRS.2017.2653186.

- Liang, C., and E. J. Fielding (2017), Interferometry With ALOS-2 Full-Aperture ScanSAR Data, IEEE Transactions on Geoscience and Remote Sensing, 55(5), 2739-2750, doi:10.1109/TGRS.2017.2653190.

- Liang, C., E. J. Fielding, and M. H. Huang (2017), Estimating Azimuth Offset With Double-Difference Interferometric Phase: The Effect of Azimuth FM Rate Error in Focusing, IEEE Transactions on Geoscience and Remote Sensing, 55(12), 7018-7031, doi:10.1109/TGRS.2017.2737955.

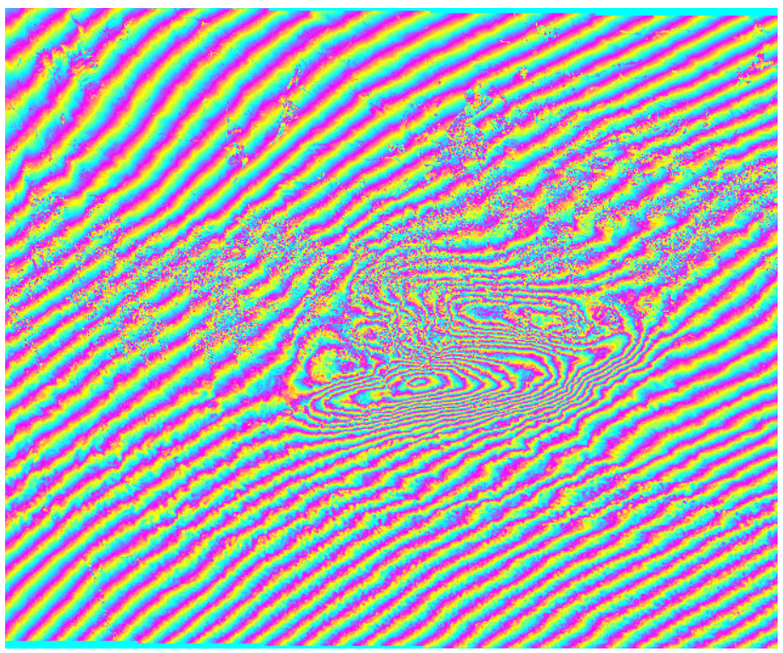
A Processing Workflow For All Acquisition Modes



2015 Gorkha earthquake in Nepal

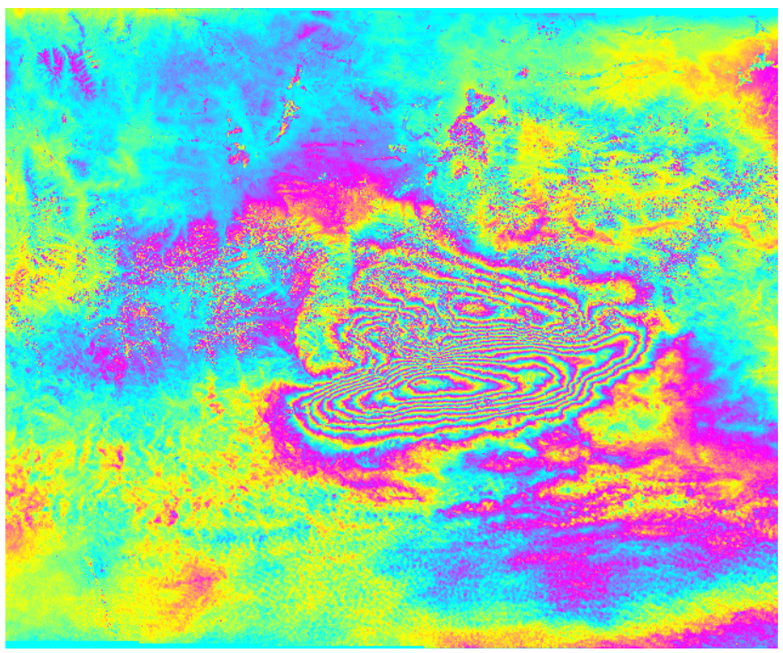
(25 April 2015, Mw7.8)

original



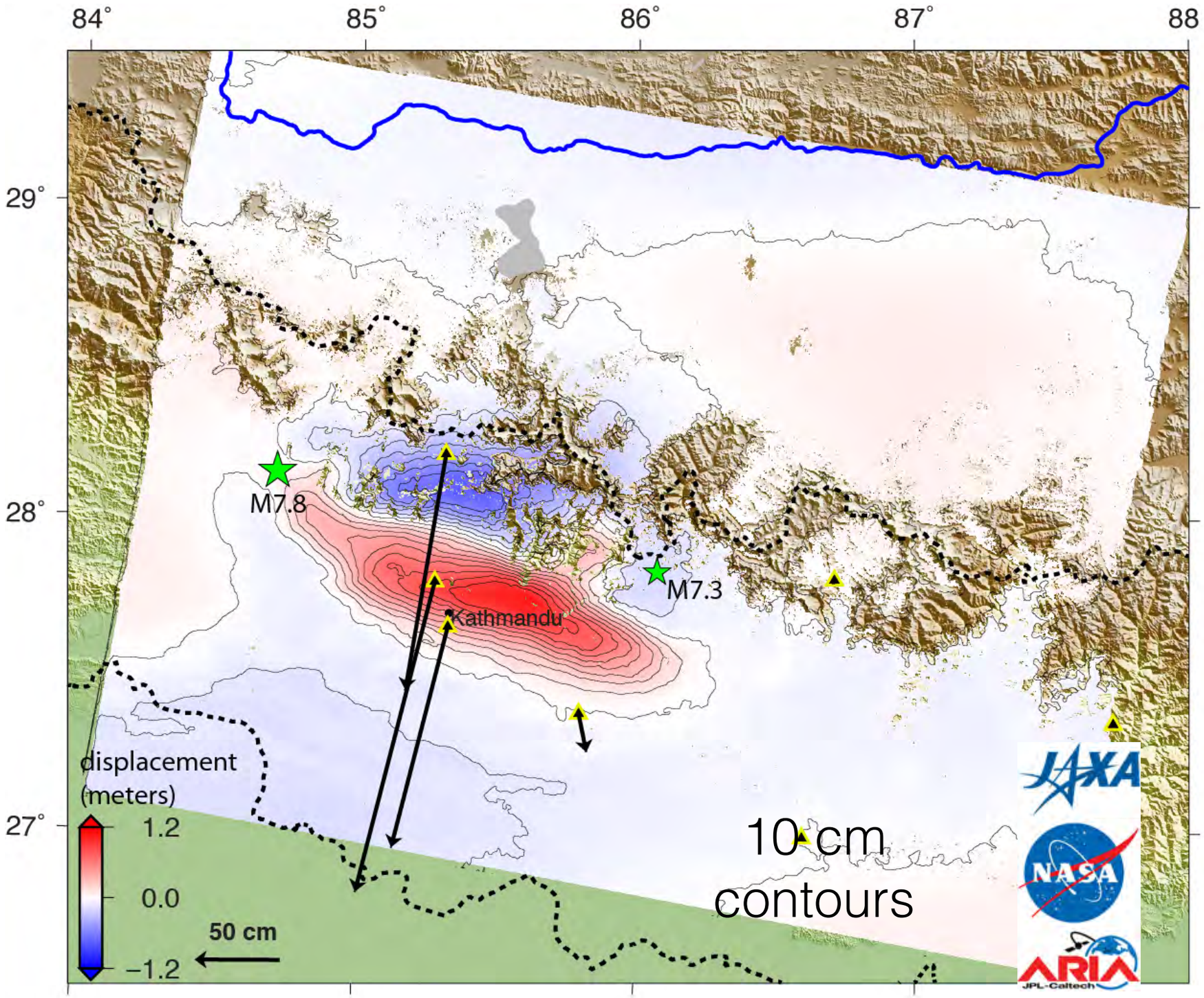
ionosphere

corrected



Nepal, 150405-150503, range bandwidth 11.9 MHz

April 25 M7.8 Earthquake in Nepal caused surface deformation and damage over 160 km long zone



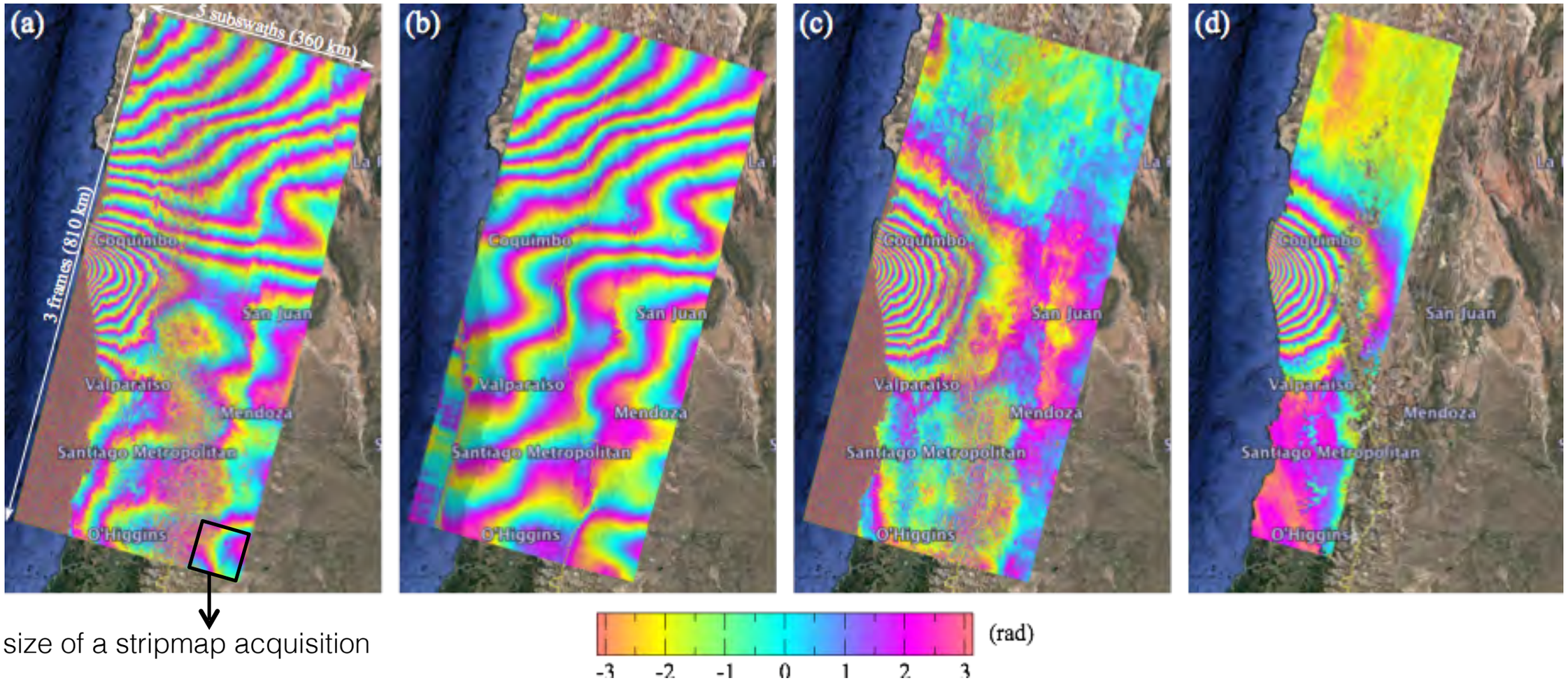
- "wide swath image" WD1 2015/02/21–05/02
- Processed with additions to JPL ISCE software
- Large fault slip at depth
- Uplift and southward motion of central Nepal, including Kathmandu
- Extensive areas of landslides and avalanches in Himalayas
- SAR data JAXA ALOS-2
- GPS data from Caltech

Yue, H., et al. (2017), Depth varying rupture properties during the 2015 Mw 7.8 Gorkha (Nepal) earthquake, *Tectonophysics*, *714-715*, 44-54, doi:10.1016/j.tecto.2016.07.005.

2015 Illapel earthquake (range)

(September 16, 2015 Mw8.3)

original | ionosphere | corrected | C band S1A



Chile, 150730-150924 Range Bandwidth: 11.9 MHz

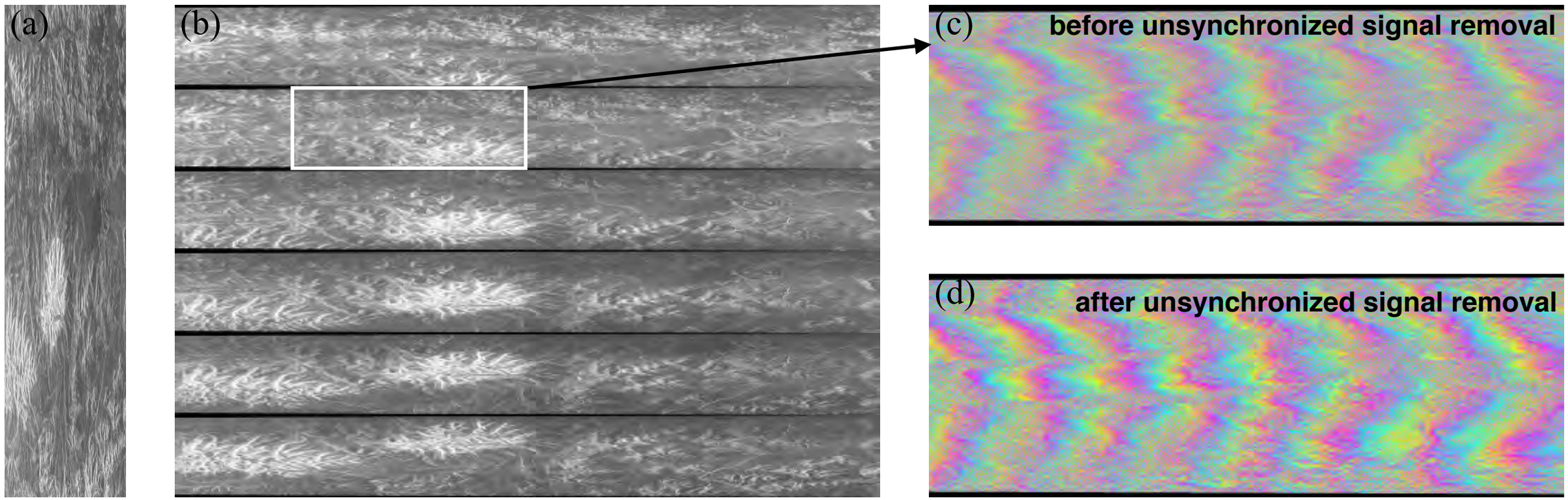
Melgar, D., W. Fan, S. Riquelme, J. Geng, C. Liang, M. Fuentes, G. Vargas, R. M. Allen, P. M. Shearer, and E. J. Fielding (2016), Slip segmentation and slow rupture to the trench during the 2015, Mw8.3 Illapel, Chile earthquake, *Geophysical Research Letters*, *43*(3), 961-966, doi:10.1002/2015GL067369.

From full-aperture data to burst-by-burst processing

full-aperture SLC

bursts pulled out

burst interferogram



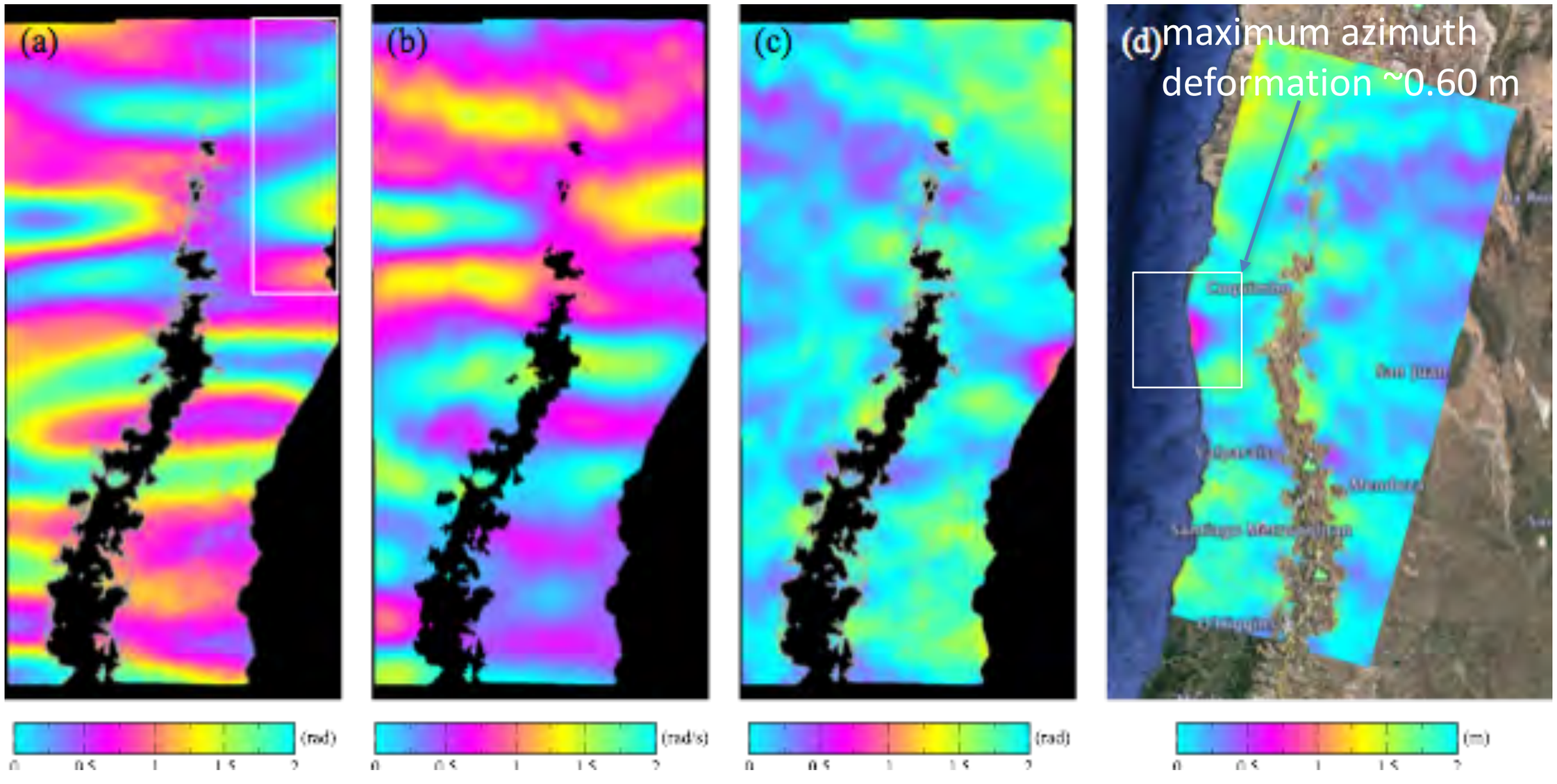
Data volume of bursts is only about 1/5 of that of full-aperture SLC.

`Nepal, 150222–150503, subswath 5`

2015 Illapel earthquake (azimuth)

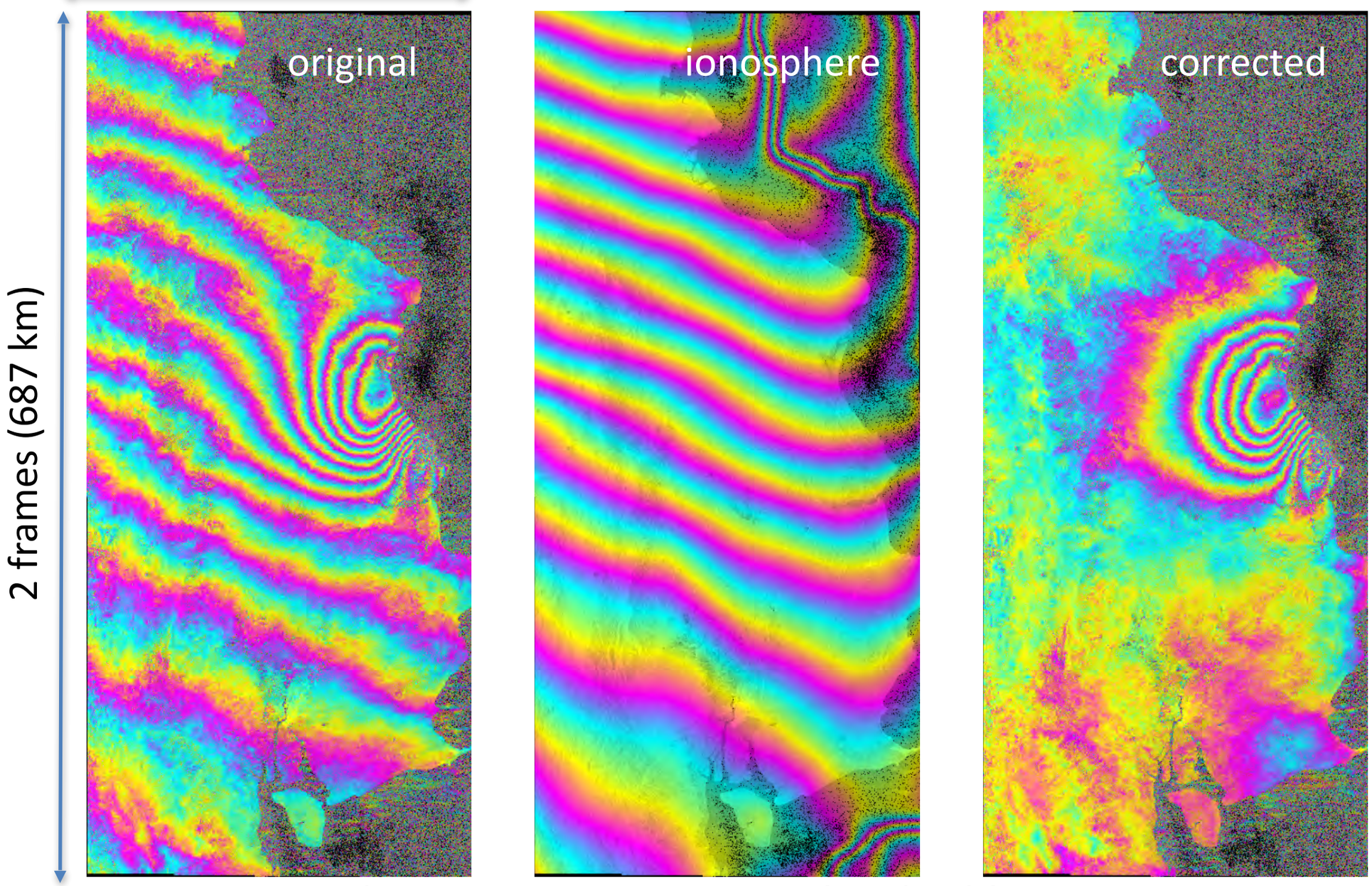
(16 September 2015, Mw8.3)

original MAI | ionospheric shift | corrected MAI | geocoded MAI



2016 Ecuador earthquake

(16 April 2016, Mw7.8)

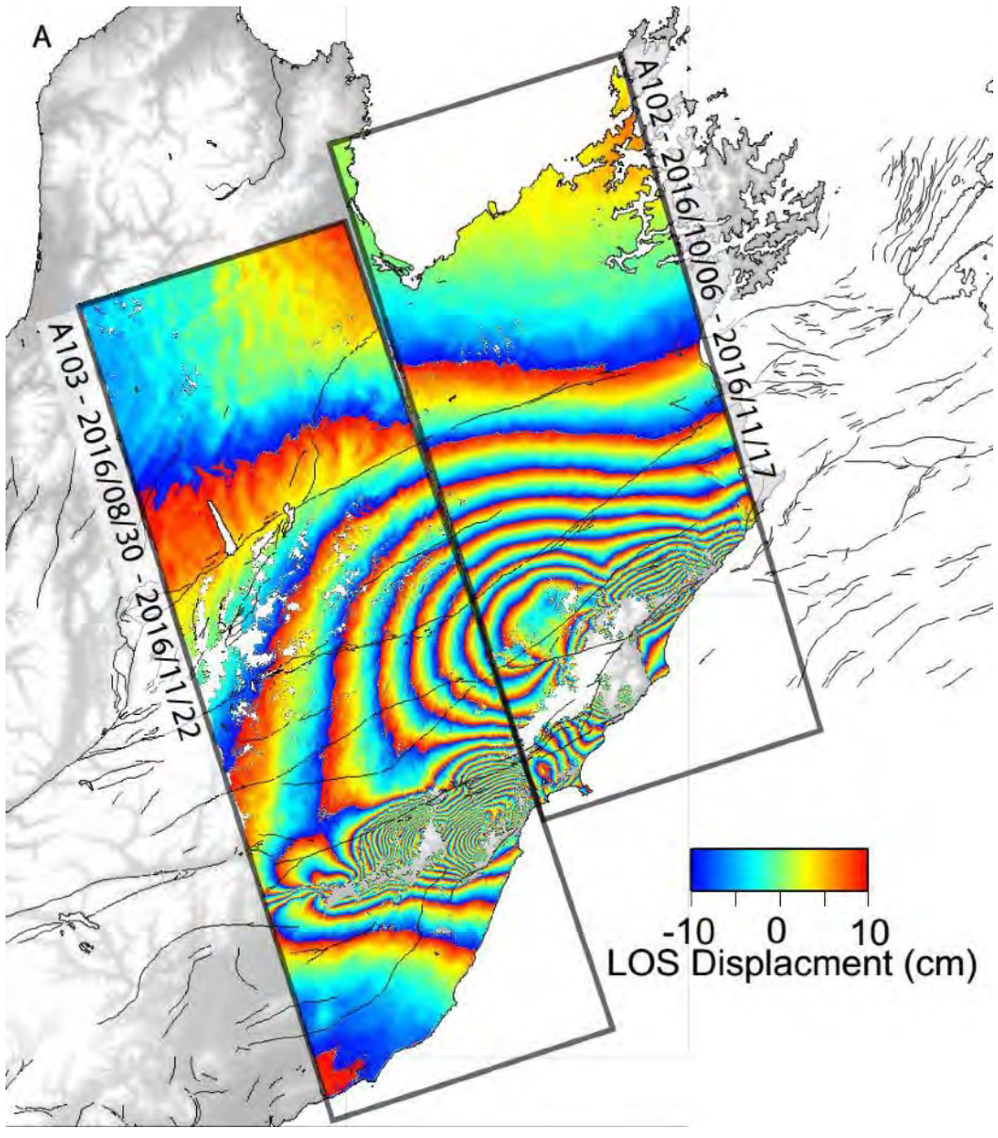


Ecuador: 160401-160429 range bandwidth 11.9 MHz

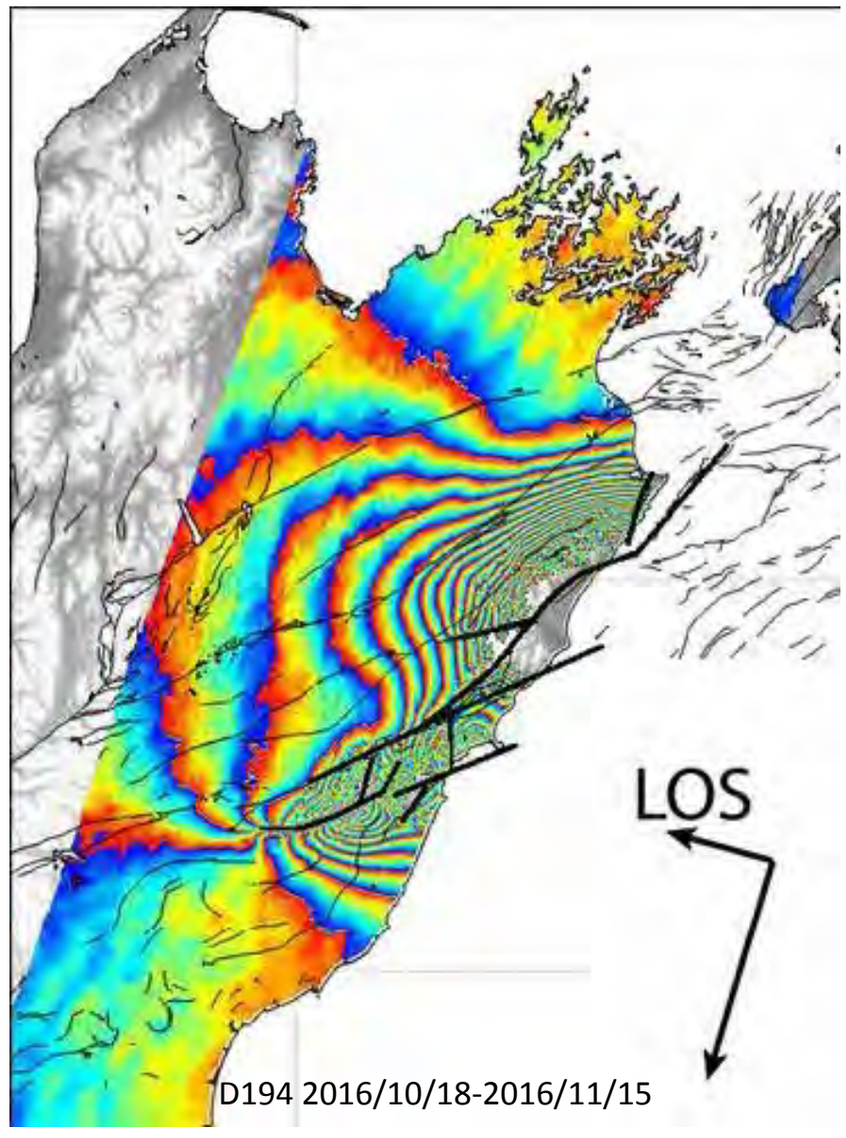
Gombert, B., et al., *in preparation*, A Bayesian analysis of the 2016 Mw 7.8 Pedernales (Ecuador) earthquake

2016 Kaikoura earthquake, New Zealand (range)

(14 November 2016, Mw7.8)



stripmap

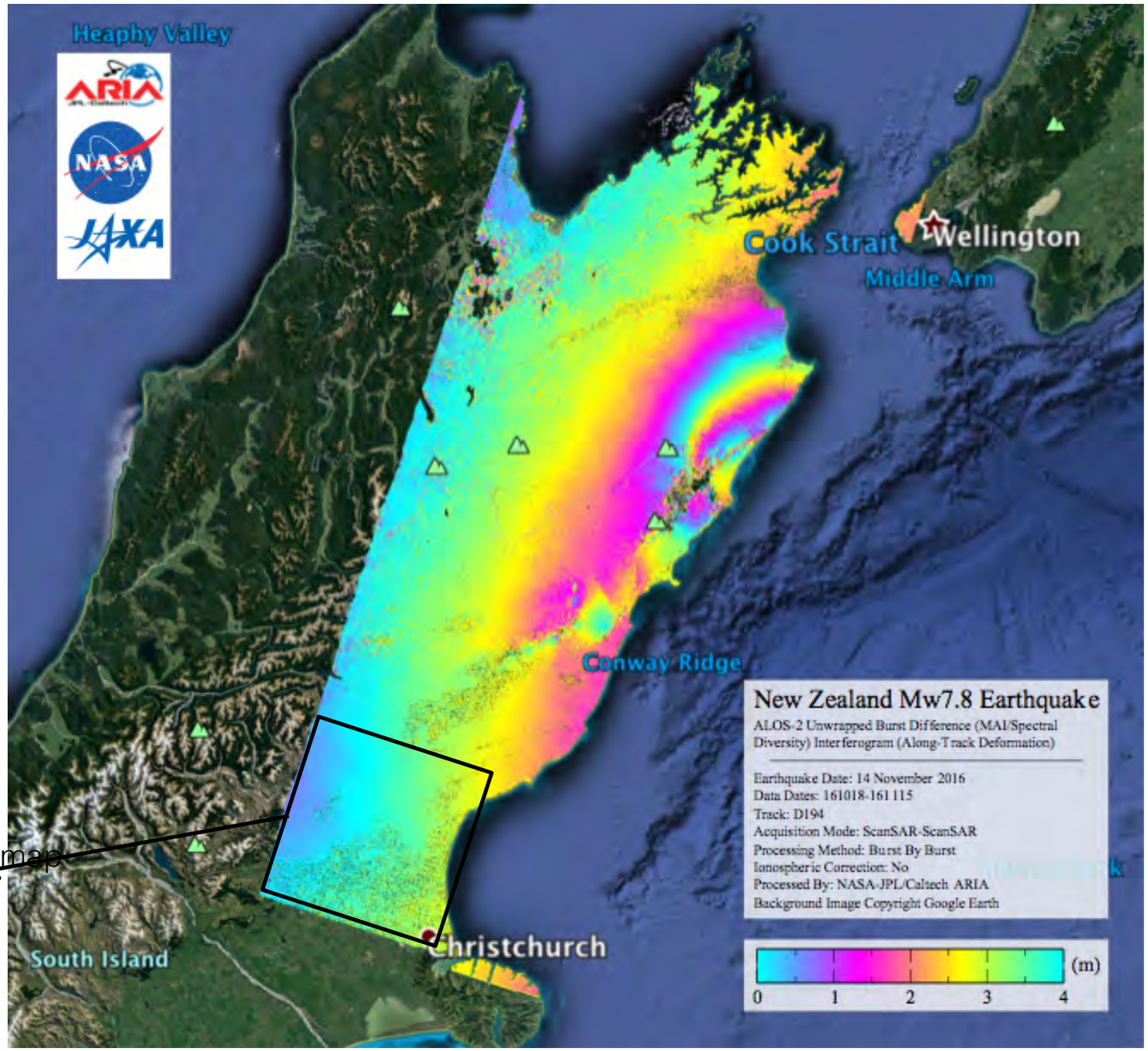


ScanSAR

Hamling, I. J., et al. (2017), Complex multi-fault rupture during the 2016 Mw 7.8 Kaikōura earthquake, New Zealand, *Science*, doi:10.1126/science.aam7194.

2016 Kaikoura earthquake (azimuth interf.)

(14 November 2016, Mw7.8)

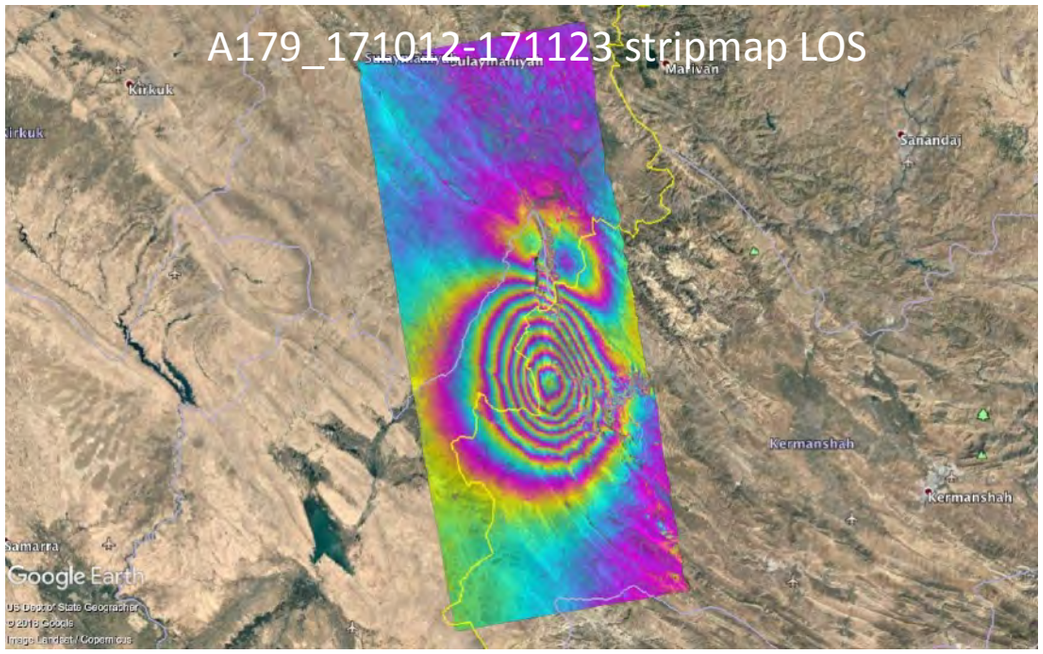


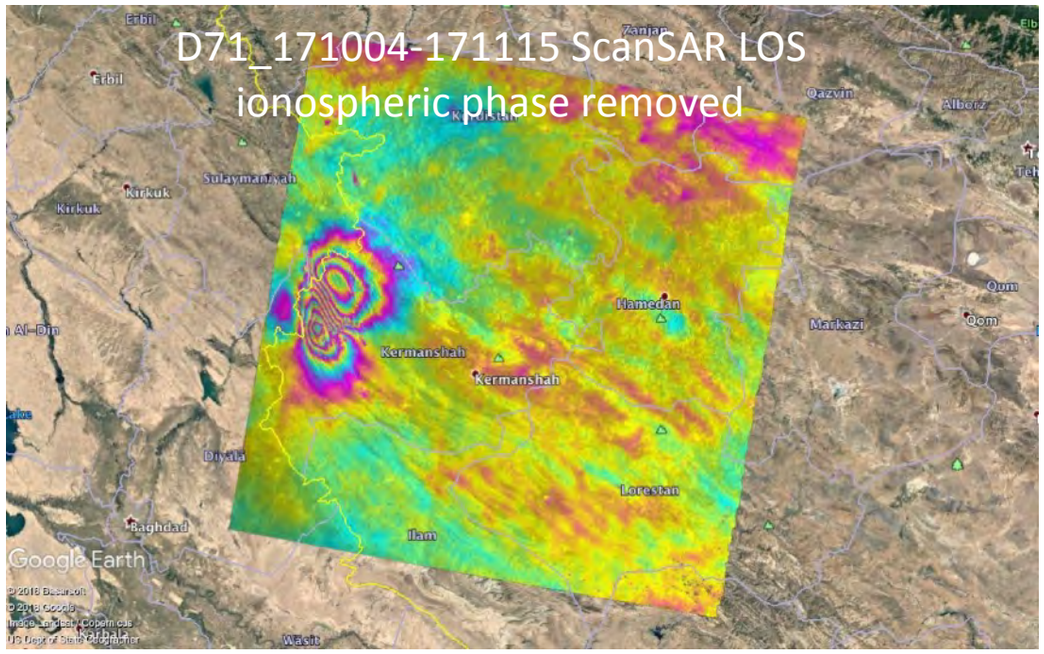
MAI up to 9 meters along-track motion

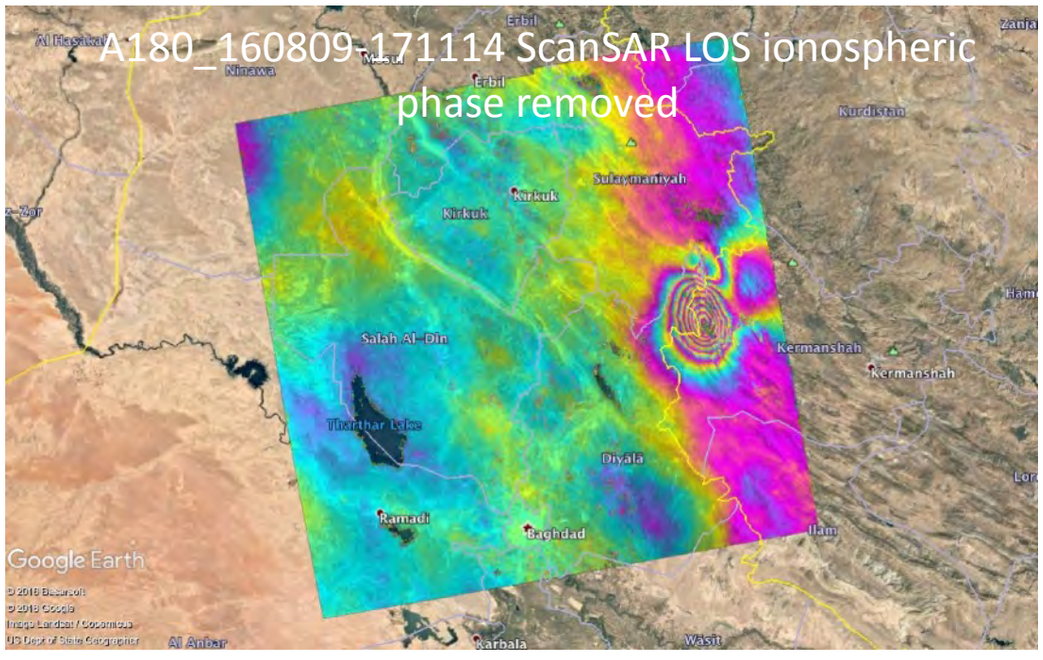
size of a stripmap acquisition

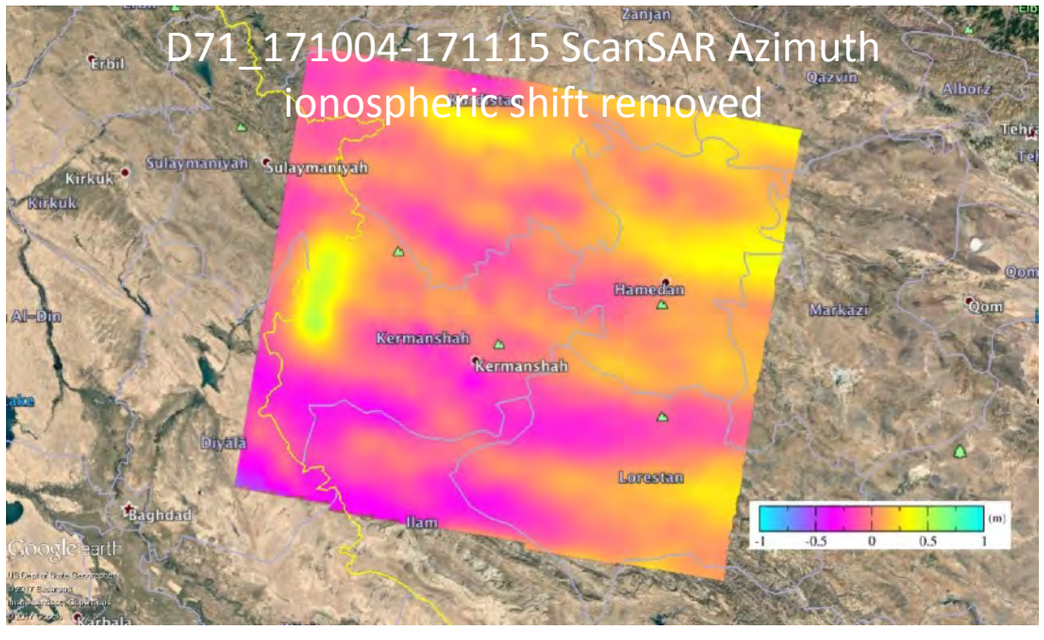
Iran–Iraq earthquake

(12 November 2017, Mw7.3)



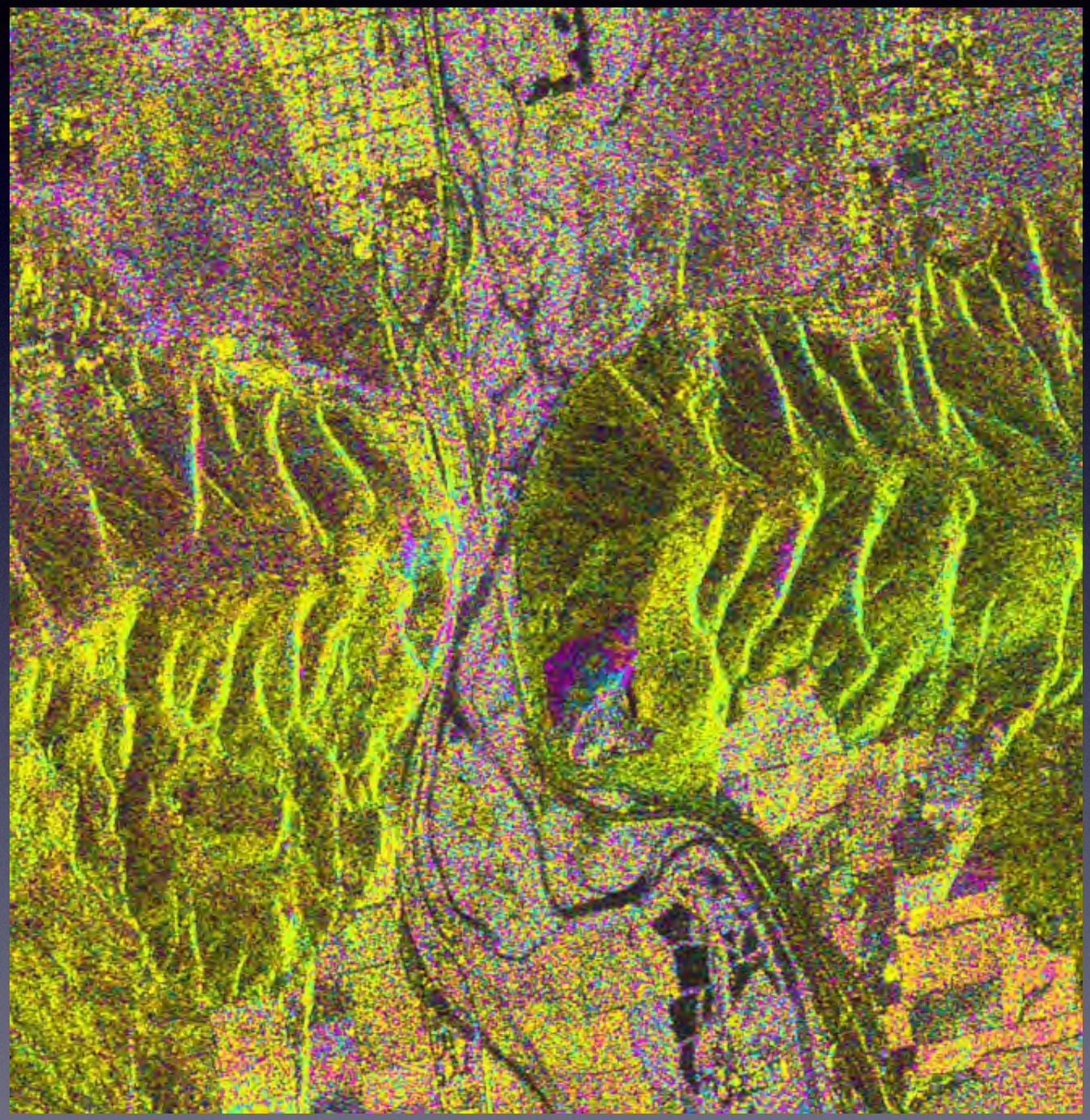






Landslides

- Large landslide block moving south of Yakima, Washington state, USA
- Close to Interstate highway I-82
- ALOS-2 stripmap coverage only every 6 months to 1-year intervals in most of USA
- Preliminary interferogram from beam F2-5, descending track 170



2017/04/24–11/06 (radar geometry)

Conclusions

- ALOS-2 wide-swath (ScanSAR) data outstanding coverage of M>7 and many M>6 earthquakes since early 2015
- ALOS-2 stripmap also excellent for mapping local details of earthquake deformation, but takes many more frames to cover large events
- New ALOS-2 module for ISCE software enables range and azimuth InSAR processing of ScanSAR full-aperture and stripmap in all combinations
- ALOS-2 module will be released with ISCE release in early 2018

Future Plans

- We will continue to process ALOS-2 interferograms for large earthquakes
- For fast-moving landslides, we will do ALOS-2 stripmap interferograms where data is available
- Landslides change quickly, so images 1-2 times per year greatly limit science and response analysis
- More frequent stripmap coverage of areas with landslides would be very helpful. Is it possible to add requests?